Carbon Loss in a Low NO_x, Slag-Tap Firing System

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Slag tap, or wet bottom firing offers the advantages of solid waste minimization and capability for firing a wide range of coals. However, conventional slag-tap designs are high NO_x emitters due to their high operating temperature. Under the USDOE Low Emission Boiler System (LEBS) program, an advanced U-fired slag-tap firing system has been developed with NO_x levels of approximately 86 g/GJ (0.2 lbs/MBtu), comparable to lower temperature state-of-the-art dry firing. In “once-through” operation, about one-half of the ash in the fuel is discharged from the firing chamber in the form of slag. In commercial U-fired boiler operation, flyash is often recycled to the firing chamber for vitrification, reducing or eliminating the fly ash stream.

U-firing consists of a down fired chamber with a slag screen separating the firing chamber from the radiant furnace. Commercial, LEBS U-fired boilers may consist of two firing chambers with multiple low- NO_x pulverized coal burners on each side of the radiant furnace. Firing conditions are such that stable flames with high carbon conversion are achieved even when the burners are operated fuel rich to minimize NO_x emissions. Local temperatures within the firing chamber are high enough throughout the chamber to liquefy the ash to sufficiently low viscosity so that it flows down the wall and can be extracted easily from the bottom of the firing chamber. Reburning involves the injection of some pulverized coal after the main flame zone, either before or after the slag screen separating the firing chamber from the radiant furnace.

LEBS firing system development was carried out with a 29 MWt, U-fired test facility (UFTF) shown in Figure 1. NO_x was controlled through the use of a low-NOx burner combined with either air staging or coal reburning. The system was operated without ash recycle and the carbon content of the slag was very low (< 1% wt.) for all firing conditions. While carbon in the flyash generally increased with decreasing NOx, the total carbon loss(bottom slag plus flyash), was low even under low-NOx firing conditions.. This suggests that in a slagging system with ash recycle, NOx can be controlled with high carbon conversion and low unburned carbon.

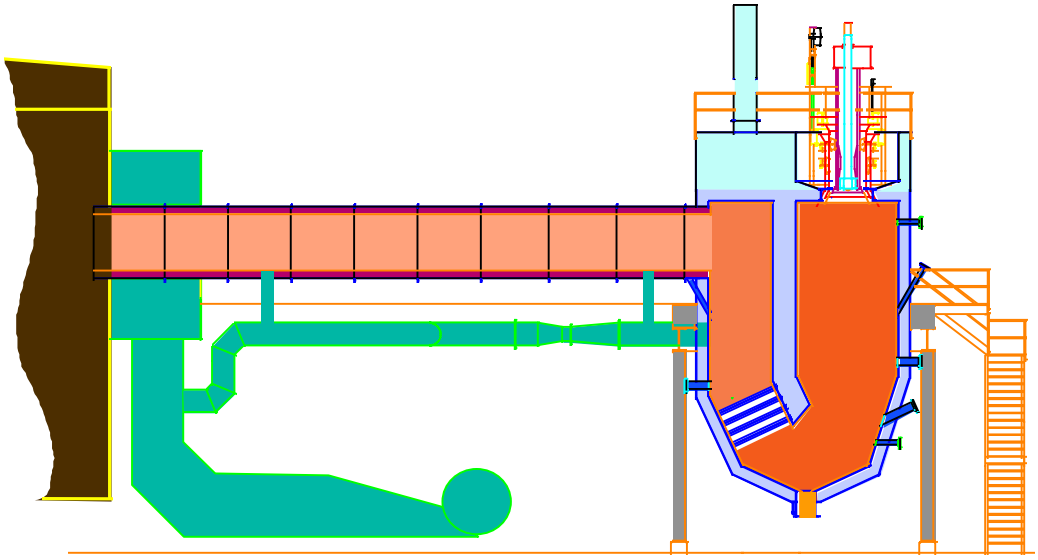

Figure 1 LEBS U-fired Test Facility

The LEBS test program provided comparative performance data for two large scale burner designs - DB Riley's Controlled Combustion Venturi, CCV® dual air zone burner and a baseline burner currently used in existing commercial U-fired systems. As part of the test program carbon loss data were obtained by collecting flyash samples while operating with both staged and unstaged combustion conditions. The LEBS U-fired test facility carbon loss data for the CCV and baseline burners is summarized in the following table for two important US steam coals.

Summary of LEBS U-fired Test Facility Unburned Carbon Results

	Unburned Carbon Range(% of heat input)				
	Riley CCV Dual Air Zone Burner			Baseline Burner	
	unstaged	air staging	reburning	unstaged	air staging
Illinois No.5 Coal 14.9 %H20 33.8 % Volatile 9.9 % Ash 10667 Btu/lb HHV as rec.	0.28-0.48	0.38-1.19	0.35-1.35		
Appalachian Blend 3.8 %H20 29.7 % Volatile 10.5 % Ash 13220 Btu/lb HHV as rec.		0.39-1.27		0.52	0.60

The range in the data reflects changes in the location of the combustion air ports used for the introduction of intermediate and final burnout air as well as changes in the reburn coal injection location. The carbon loss results firing Illinois No. 5 coal show some increase in unburned carbon for both air and fuel staging. Depending on the burnout air location the increase in unburned carbon can be kept close to the unstaged losses. Similar carbon loss results were obtained for the east Appalachian blend (10.5% ash) during air staging tests as were achieved for the Illinois No. 5 coal (9.9% ash).

The highest carbon conversion in the test facility results, i.e. 0.28 % carbon loss (based on heat input) represents a flyash carbon content of 4% for this coal ash level. This lower range of the test facility data is comparable to flyash carbon levels of 2% measured at a 320 MW U-fired slag-tap boiler operating unstaged with 9.25% ash, Ruhr coal.

Carbon conversions from single burner test furnaces are typically lower than from multiple burner commercial furnaces. However the carbon conversion in the LEBS U-fired test furnace was found to be higher than comparable results obtained from DB Riley's dry-bottom test facility operating under low NO_x firing conditions. Comparison of these results highlight the importance of both burner and furnace design parameters on system performance. Improvement in power plant carbon conversion efficiencies need to be considered on a case-by-case basis, accounting for variations in fuel characteristics, burner design, fuel/air distributions, furnace geometry and operating conditions.